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Grid integration of robotic telescopes

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Robotic telescopes and grid technology have made significant progress in recent years. Both innovations offer important advantages over conventional technologies, particularly in combination with one another. Here, we introduce robotic telescopes used by the Astrophysical Institute Potsdam as ideal instruments for building a robotic telescope network. We also discuss the grid architecture and protocols facilitating the network integration that is being developed by the German AstroGrid-D project. Finally, we present three user interfaces employed for this purpose.

1 Introduction

In recent years the first robotic telescopes came to operation and many of them already routinely collect data without human interaction. A natural next step in automated astronomy is the integration of these telescopes into a network. A network of distributed telescopes can perform new types of observations which cannot be accomplished with individual instruments. Important examples include continuous long-term monitoring of objects independent of day and night cycles and weather, rapid response to transient objects and multiwavelength campaigns.

The Astrophysical Institute Potsdam (AIP) currently operates five robotic telescopes and is pursuing their integration into a network. This effort is supported by AstroGrid-D, which is the German astronomy community grid. Here *grid* refers to a distributed network of loosely coupled resources with a common, user-friendly infrastructure. The AstroGrid-D collaboration consists of 20 people from fourteen German institutes under the leadership of the AIP. The project has been funded by the German Ministry of Education and Research (BMBF) for a period of three years. The network will be built on grid technology, which provides an ideal framework for a robotic telescope network. For example, it provides solutions for the management of Virtual Organization[1], grid resources, computational jobs and observation, data and metadata. In addition, it allows the immediate access to computational and storage resources for data analysis.

2 Robotic telescopes of the AIP

With control of five robotic telescopes the AIP provides the necessary hardware for the development and operation of a telescope network. The telescopes are RoboTel, STELLA-I and II, Wolfgang and Amadeus.

- RoboTel is located at the AIP. It is a 0.8 m telescope equipped with a CCD camera for imaging and photometry. In addition to its science core-program, half of the observation time is reserved for schools and universities. The remaining observation time is dedicated to testing of new instruments, software and methods for the STELLA-I and II telescopes.
- The STELLA robotic observatory is located at Izaña observatory in Tenerife, Spain. It consists of two 1.2 m telescopes, STELLA-I and STELLA-II. STELLA-I is equipped with a spectrograph and has been operating since May 2006. STELLA-II will be equipped with an imaging photometer. Its commissioning starts at the end of 2007. Scientific objectives are: Doppler imaging, the search for extrasolar planets, spectroscopic surveys and support observations for simultaneous observations with larger facilities.
- Wolfgang and Amadeus (Strassmeier et al. 1997) are located at the Fairborn Observatory in Arizona. They are two 0.75 m telescopes equipped with photomultipliers for photometry. The scientific objectives are the participation in multi-site observing campaigns and studies of variability timescales and life times of starspots, requiring monitoring of stars over periods of years.

Further details regarding RoboTel and STELLA can be found in Granzer (2006) and Strassmeier et al. (2004).

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[1] In grid computing, a Virtual Organization defines a collaboration of users with same access rights to grid resources.

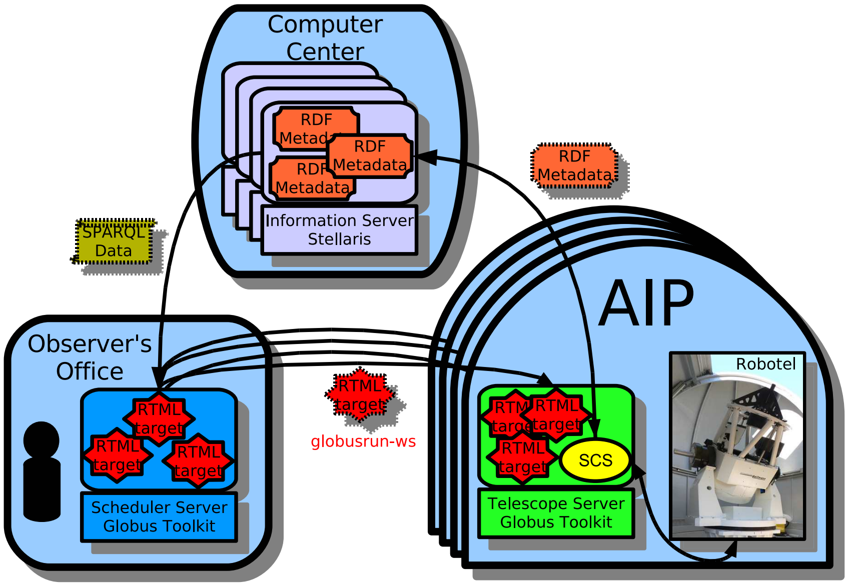

Fig. 1: Grid architecture of the robotic telescope network. Telescope servers, scheduler and the information service "Stellaris" are the main components. The management of observation requests is done through the Globus Toolkit and using RTML. Metadata is submitted in RDF to Stellaris and retrieved using the SPARQL query language.

3 Grid architecture

The grid architecture of AstroGrid-D consists of three main components which are linked through the internet: the telescope servers, a scheduler and the information service as shown in Fig. 1.

The telescope server is a computer providing a robotic control system (SCS in Fig. 1) for a telescope. Therefore it is located at the observatory. The scheduler compiles schedules for network observations, taking into account the monitoring information on the status of each individual telescope (including weather and engineering data). Some aspects regarding scheduling are discussed in Granzer et al. (2007). The information service stores and provides metadata of the entire telescope network. It plays a central role for monitoring, scheduling and data access. It can be run at a computer center.

The submission of observation requests and access to new data is provided by the grid middleware: AstroGrid-D uses the Globus Toolkit (Foster 2006) commands (such as `globusrun-ws`) of the Grid Resource and Allocation Manager (WS GRAM) . The AstroGrid-D information service is called "Stellaris" (Högqvist, Röblitz & Reinefeld 2007). It is a development of the project.

For the information exchange the AstroGrid-D architecture uses two protocols: the "Remote Telescope Markup Language" (RTML, Hessman 2006) and the "Resource Description Format" (RDF 2007). RTML is an XML format for the description of telescope metadata, such as observation requests, observation schedules, source catalogs, telescope hardware and weather information. RDF is a standard for storing information. It is derived from graph theory and represents information in triples as *subject*, *predicate*, *object*. Fig. 2 shows part of a RDF graph representing the static metadata of the STELLA-I telescope. The RDF/XML and Notation 3 formats exist as RDF representations. Since Stellaris uses RDF exclusively, a conversion from RTML to RDF became necessary, in order to store RTML metadata. Such a conversion has been developed using a XSL transformation (XSLT 2007). The XSLT (rtml2rdf.xsl 2007) is the first open source transformation of arbitrary XML documents into RDF/XML. The retrieval of information from Stellaris is accomplished using SPARQL (2007), the query language for RDF.

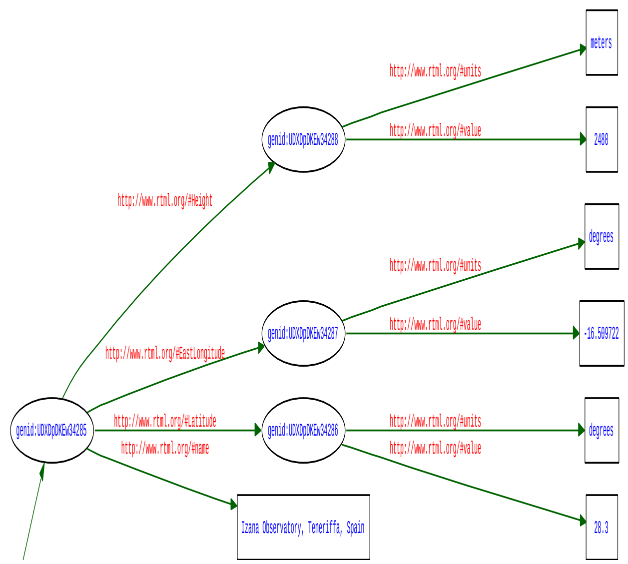

Fig. 2: Partial RDF graph of the static metadata of the robotic telescope STELLA-I. The represented region shows the information regarding the telescope's location.

4 User interfaces

User interaction with the network is necessary for monitoring and controlling. Three interfaces have been developed and are discussed below.

Stellaris provides a user interface for SPARQL queries. It is accessed through a web browser as shown in Fig. 3. If the example query is submitted, Stellaris returns a geographic location of the available telescopes sorted by altitude. In addition all SPARQL queries can be executed via the command line and scripts using the “Redland Language Bindings” (librdf 2007).

A second web browser user interface is the Telescope Map (Telescope Map 2007) shown in Fig. 4. It is based on Google Maps (Google Maps 2007) and shows locations of observatories by markers. Selection of these markers provides additional information such as the available telescopes and their states. This map is useful for monitoring of network status and observation, in particular because additional information can be added.

A third web browser user interface for time-based information is the Grid Timeline (2007) shown in Fig. 5. It can be considered as complementary to the Telescope Map. It uses the service of Simile (2007), which provides a DHTML-based AJAXy widget for visualizing timing information. The Grid Timeline is currently used for job monitoring and can therefore be easily applied to monitoring of robotic observations.

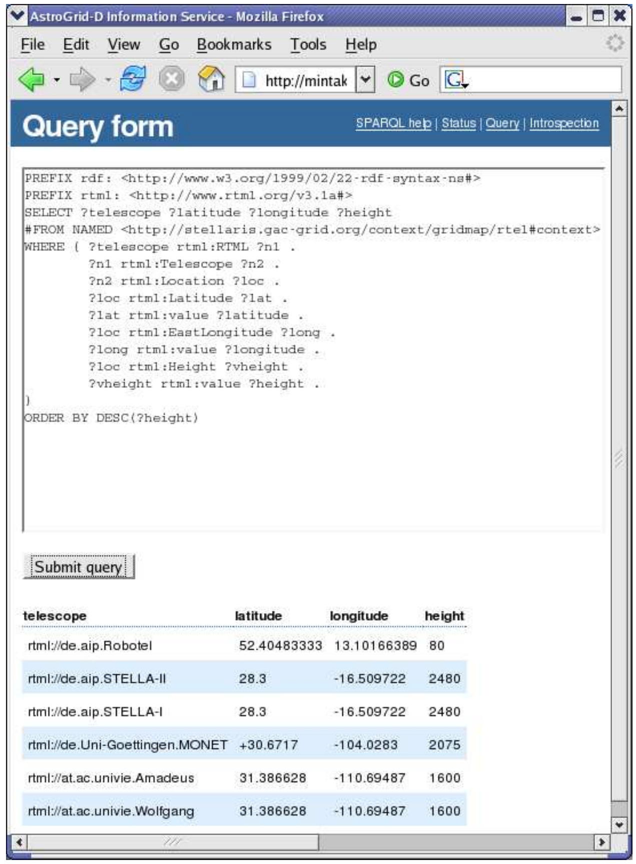

Fig. 3: SPARQL query form of the web browser user interface of Stellaris. The query displayed here in the top section will retrieve the location of available telescopes sorted by altitude. The result can be seen in the lower half of the window.

5 Conclusion

Five robotic telescopes are operated by the AIP and are prepared for network integration. An architecture for the integration of these telescopes to a network using grid technology has been developed within AstroGrid-D and its main components are available. RTML metadata of telescopes and observations can be provided to, and received from, the information service. User interfaces are available for easy access to this information.

6 Outlook

The next steps will be the implementation of the Globus job management WS GRAM and the development of the scheduler. Then the network can undergo testing, conduct its first observations and finally participate in campaigns with other telescopes.

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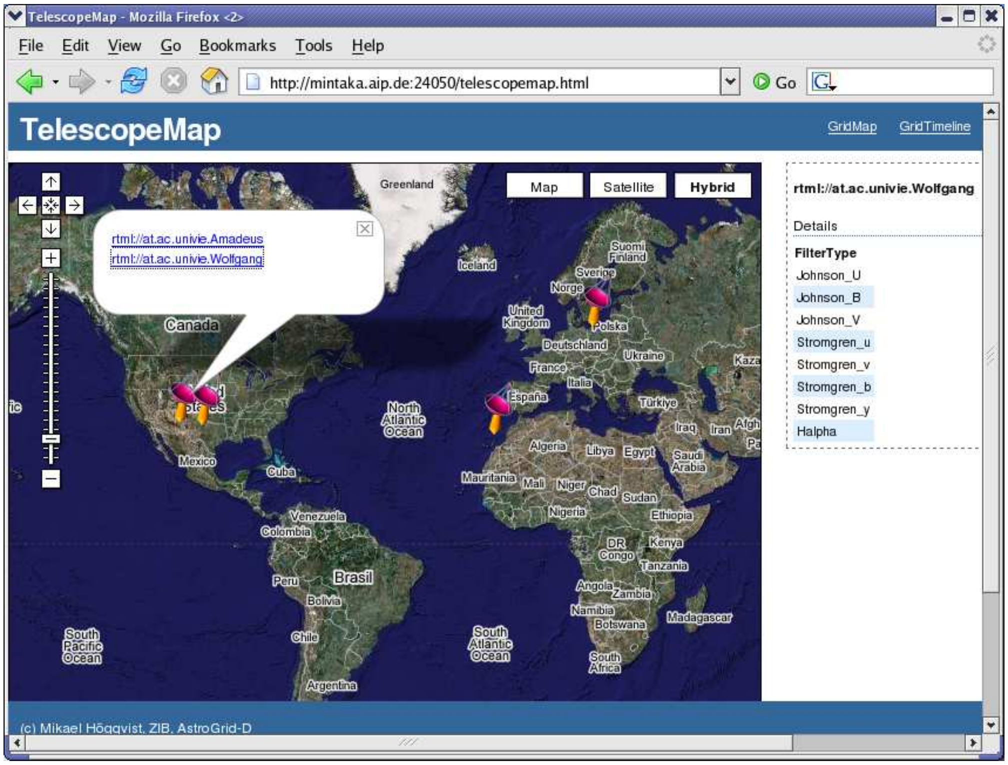

Fig. 4: The Telescope Map showing the locations of observatories by bright telescope markers. When a marker is selected additional information about the installed telescopes as well as their setup is displayed.

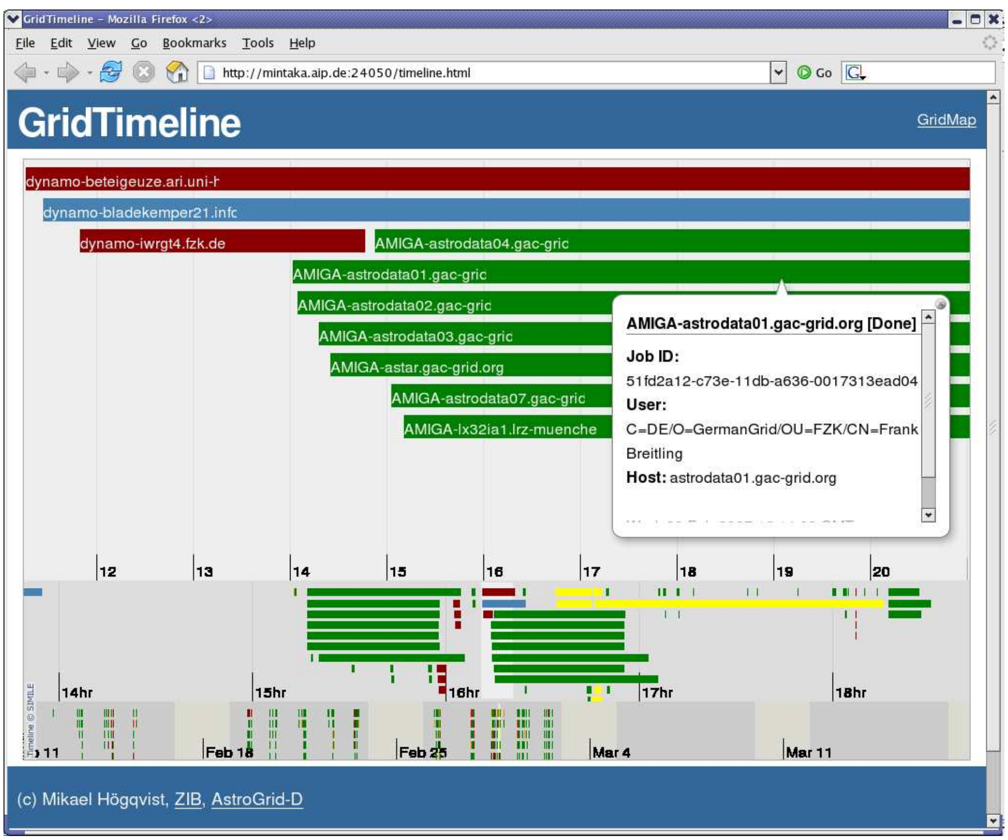

Fig. 5: The Grid Timeline showing the runtime of jobs and observations in AstroGrid-D. Each job is represented by a horizontal bar along the time axis. From top to bottom three different time scales are visible. Additional information is displayed in a text box on selection.